AD-A031 040 ARMY ELECTRONICS COMMAND FORT MONMOUTH N J F/G 20/6

VISIBILITY AS AN ESTIMATOR OF INFRARED TRANSMITTANCE,(U)

JUL 76 J MASON, G B HOIDALE

UNCLASSIFIED ECOM-5598 NL

1 OF 1

AD

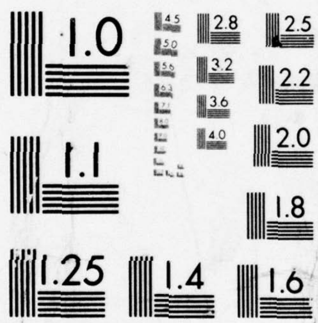
A031040

END

DATE

FILMED

11-76



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ADA031040

12

AD

Reports Control Symbol
OSD-1366

RESEARCH AND DEVELOPMENT TECHNICAL REPORT

ECOM-5598

VISIBILITY AS AN ESTIMATOR OF INFRARED TRANSMITTANCE

By

J. Mason
G.B. Hoidale

Atmospheric Sciences Laboratory
US Army Electronics Command
White Sands Missile Range, New Mexico 88002

July 1976

Approved for public release; distribution unlimited.

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY 07703

NOTICES

Disclaimers

Disposition

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ECOM-5598	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): VISIBILITY AS AN ESTIMATOR OF INFRARED TRANSMITTANCE	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. Mason ~~and~~ G. B. Hoidale	8. CONTRACT OR GRANT NUMBER(s) Jul 76
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Atmospheric Sciences Laboratory, White Sands Missile Range, NM 88002	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: ~~DA Task~~ 1T161102B53A-19
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Electronics Command, Fort Monmouth, NJ 07703	12. REPORT DATE: July 1976
	13. NUMBER OF PAGES: 25 26p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): DA-1-T-161102-B-53-A	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Infrared-radiation
Haze
Fog
Propagation
Dust
Smoke
Visibility

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

To assess the utility of visibility as an indicator of transmittance in the infrared, models depicting haze, fog, smoke, and dust were constructed such that all yielded identical transmittances at 0.55μm (center of the visible spectrum), and transmittances at several infrared wavelengths (due to scattering only) were calculated. Results show that significant errors occur if visibility is relied upon.

micrometers

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

037620

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

The authors wish to thank Dr. George Goedecke for assistance in adapting the ASL single scattering code to this problem and Dr. Richard Gomez for helpful discussions during preparation of this report.

CONTENTS

INTRODUCTION

With the growing emphasis on electro-optical systems in the Army's tactical arsenal, it is becoming more important to understand the atmosphere's effect on light transmission in the battlefield environment. One element of concern is the effect of suspended particulate material, and this especially in the infrared (1-15μm) region of the spectrum. At the present time, the Army has no field-hardened transmissometer for application in the battlefield environment, and where it is necessary to predict the performance of an aiming device or target designator, there is a tendency to apply what information is available - namely, the met observer's estimate of visual range. Empirical relations between visual range and IR transmittance have been devised and used [1,2]. Is visual range really indicative of transmittance in the near infrared?

Some examples of calculated effects due only to particulate light scatter using model aerosols of varying composition are presented. The purpose is to suggest the degree to which transmission in the IR can be affected by changes in the particulate content alone and how accurately (or inaccurately) an estimate of propagation in the visible region indicates those effects.

To establish a basis for comparison, we assume that visual range (defined below) is inversely proportional to the logarithm of monochromatic transmittance at 0.55μm, the center wavelength for human visual perception. All calculations are then normalized to a transmittance of 0.45 over a 1 km path at this wavelength which corresponds to a visual range of 5 km. That is, an observer would estimate the same visual range in every case.

PARTICULATE MODELS

The ASL single scattering transmission code (PGAUSS) [3] is used for the calculations and gaseous absorption effects are not included. The particulate model supposes a two-component aerosol in the combinations:

Dry Haze + Smoke	Wet Haze + Smoke	Fog + Smoke
Dry Haze + Dust	Wet Haze + Dust	Fog + Dust

with one component predominant in varying degrees. Clearly, other aerosol conditions can obtain. These were chosen as being representative of the environment encountered during Target Signature Model Validation Tests [4] conducted at Fort Knox, KY, in August 1974 by the Army Materiel Command. The size distributions pertaining to each component are given in Table 1 and the optical constants are given in Table 2.

TABLE 1

ATMOSPHERIC PARTICULATES AT FORT KNOX, KY

Designation	Composition	Size Distribution: Type	Size Distribution: Representation	Constants	Radius (r) Range (μm)
Dry haze	Soil	Deirmendjian haze C	$n(r) = 0$	-	$r < 0.03$
			$n(r) = c \times 10^4$	-	$0.03 \leq r \leq 0.1$
			$n(r) = cr^{-4}$	-	$0.1 < r \leq 1.0$
Wet haze	Water		$n(r) = 0$	-	$r < 1.0$
Dust	Soil	Power Law (Junge)	$n(r) = cr^{-\beta}$	$\beta = 3.0$	$0.1 < r < 10$
Smoke	Carbon	Log-normal	$\left\{ n(r) = \frac{1}{r \ln(\sigma_g \sqrt{2\pi})} \exp \left\{ -\frac{1}{2} \left[\frac{\ln(r/r_g)}{\ln\sigma_g} \right] \right\}^2 \right\}$	$\sigma_g = 0.30$, $r_g = 0.25$	$0.1 < r < 0.4$
Fog	Water			$\sigma_g = 0.30$, $r_g = 5.0$	$4.85 < r < 5.15$

TABLE 2

OPTICAL CONSTANTS OF DRY HAZE, DUST, SMOKE, WET HAZE, AND FOG IN THE 0.34 TO 10.6 μm RANGE

	Dry Haze, Dust [5]		Smoke [6, 7, 8]		Wet Haze, Fog [9]	
λ(μm)	n	k	n	k	n	k
0.34	1.65	0.005	1.6	-	1.345	0.0
0.40	1.65	0.005	1.6	0.5	1.339	1.86 E-9
0.47	1.65	0.005	1.6	0.5	1.336	9.52 E-10
0.55	1.65	0.005	1.6	0.5	1.330	1.96 E-9
0.66	1.65	0.005	1.6	0.5	1.330	1.88 E-8
0.75	1.65	0.005	1.6	0.5	1.330	1.56 E-7
0.90	1.65	0.005	1.7	0.5	1.328	4.86 E-7
1.06	1.65	0.005	1.7	0.7	1.326	5.0 E-6
1.25	1.65	0.005	1.7	0.7	1.323	4.2 E-5
1.5	1.65	0.007	1.7	0.7	1.319	1.1 E-4
1.75	1.64	0.009	1.7	0.7	1.313	1.1 E-4
2.0	1.64	0.010	2.1	0.8	1.306	1.1 E-3
2.4	1.64	0.014	2.0	0.8	1.279	9.56 E-4
2.8	1.61	0.044	2.2	0.8	1.142	1.15 E-1
3.4	1.68	0.021	2.3	0.8	1.420	1.95 E-2
4.0	1.64	0.018	2.4	0.8	1.351	4.6 E-3
4.7	1.61	0.018	2.1	0.8	1.330	1.57 E-2
5.5	1.56	0.018	2.4	0.8	1.298	1.16 E-2
6.6	1.41	0.071	2.4	0.8	1.334	3.56 E-2
7.5	1.56	0.071	2.4	0.8	1.304	3.26 E-2
9.0	1.65	1.240	2.3	0.8	1.260	3.99 E-2
10.6	1.87	0.079	2.4	2.5	1.179	7.23 E-2

n = real component of the complex refractive index

k = imaginary component of the complex refractive index

Dry Haze-Wet Haze

The term dry haze refers to the natural background of particulates present in the air under low humidity conditions, i.e., when the relative humidity is less than 70 percent. Wet haze refers to the natural background of particulates when the relative humidity is greater than 70 percent. Both the dry haze and the wet haze are represented by the Deirmendjian Haze C size distribution [10]. The optical constants for wet haze are assumed to be those of water, while the optical constants for dry haze are assumed to be those of soil particles. Thus, no allowance is made for solid cores or dissolved material in the droplets.

A more extensive treatment of the effect of relative humidity dependent particulates upon transmission (e.g., Hänel [11]) was considered. However, for the purpose of demonstrating the unreliability of visibility estimates for inferring IR transmittances, the models selected proved adequate.

Dust

Dust refers to the larger soil particles injected into the air as a result of vehicular traffic, primarily over ungraveled dirt roads and unconsolidated natural terrain. The size distribution is represented by a power law selected to reflect higher concentrations of particles than for dry haze. The optical constants are the same as for dry haze, although the composition of the two categories is likely to differ.

Smoke

Smoke refers mainly to vehicle exhaust which is assumed to consist of carbon particles. The smoke is represented by a log-normal size distribution. The values of the optical constants were based on the works of Dalzell and Sarofim [6], Twitty and Weinman [7], and Foster and Howarth [8].

Fog

Fog refers to water droplets. The individual droplets are of a much larger size than wet haze and the size distribution is log-normal in contrast to the Haze C model for wet haze.

TRANSMITTANCE

The ASL scattering model used for this analysis included only single scattering, and all calculations were normalized to a 5 km visibility at a wavelength of $0.55\mu m$ using the relation [12]

$$V = \frac{1}{\sigma_{0.55}} \ln\left(\frac{1}{\varepsilon}\right)$$

where V is the visual range in kilometers and $\sigma_{0.55}$ is the extinction coefficient at a wavelength of 0.55μm, and $\varepsilon = 0.02$. Thus, the total particulate concentration was adjusted to yield this condition. Six sets of two-component particulate conditions were simulated. In each, either dry haze, wet haze, or fog was regarded as the major constituent with either dust or smoke as the minor constituent. The relative composition of each set was varied through the number concentrations of each component.

Dry Haze + Smoke

Figure 1 shows the transmittance in the visible and IR for three combinations of background dry haze and the locally generated smoke. The decrease in transmittance at 9μm was attributed to energy absorption by the dry haze [13]. The number concentrations represent the total number of particles within the applicable size range and appropriate to a 5 km visual range.

Dry Haze + Dust

In this case the minor constituent smoke was replaced by the dust, thus simulating effects of vehicular traffic. Figure 2 shows that the effect with dust at 9μm was more pronounced than with smoke as the minor constituent.

Wet Haze + Smoke

The transmittances for three combinations of wet haze and smoke are depicted in Figure 3. The decrease in transmittance at 1.5μm is attributed to smoke. In the 2.5 to 3.0μm region, the effect of water absorption is evident.

Wet Haze + Dust

Figure 4 shows the relative effects of replacing the "battlefield smoke" with "battlefield dust." The effect of dust absorption at 9μm is noticeable.

Fog + Smoke

The last background to be considered is fog. Figure 5 illustrates the effects of the addition of four different percentages of smoke. The transmittance patterns are in marked contrast to the previous combinations. Note that for the four cases presented, the visibility appears to be a good estimator of transmittance out to 2μm. For cases 3 and 4 the transmittance actually decreases with increasing wavelength in the range from 3 to 6μm.

Fog + Dust

In this case dust was superposed on the background fog. Figure 6 reveals that the effect of the dust is much less pronounced than that of the smoke. The notable difference in transmittance over the 4 to 10μm range for fog, as opposed to dry and wet haze, is attributed to differences in size distribution and size range.

CONCLUSIONS

These results, based on scattering effects alone, show clearly that any estimate of near infrared atmospheric transmittance based on observations in the visible region (i.e., visual range) is subject to error and is probably quite wrong. It is noted that the story is not complete until gaseous absorption effects are included (e.g., water vapor and CO_2) and that these are likely to further enhance the error.

It is also noted, however, that if the composition of the suspended particulates is known the results presented here suggest that a more accurate estimate of IR transmittance might be obtained from a two-wavelength visual range observation since the slope of the transmittance curve would then be established. It is emphasized that gaseous absorption must be included before this is seriously considered. Thus, in the case of water vapor for example, one might anticipate a set of curves for varying water vapor content - meaning that a transmittance prediction would require as inputs both absolute humidity and dual wavelength visual range data. Similar adjustments might also be required for some other minor gaseous constituents.

It is clear, nevertheless, that if prediction of IR transmittance is desirable on the battlefield, more in-situ information than is currently available will certainly be required. In addition, the simpler the method for obtaining this information the more useful it will be.

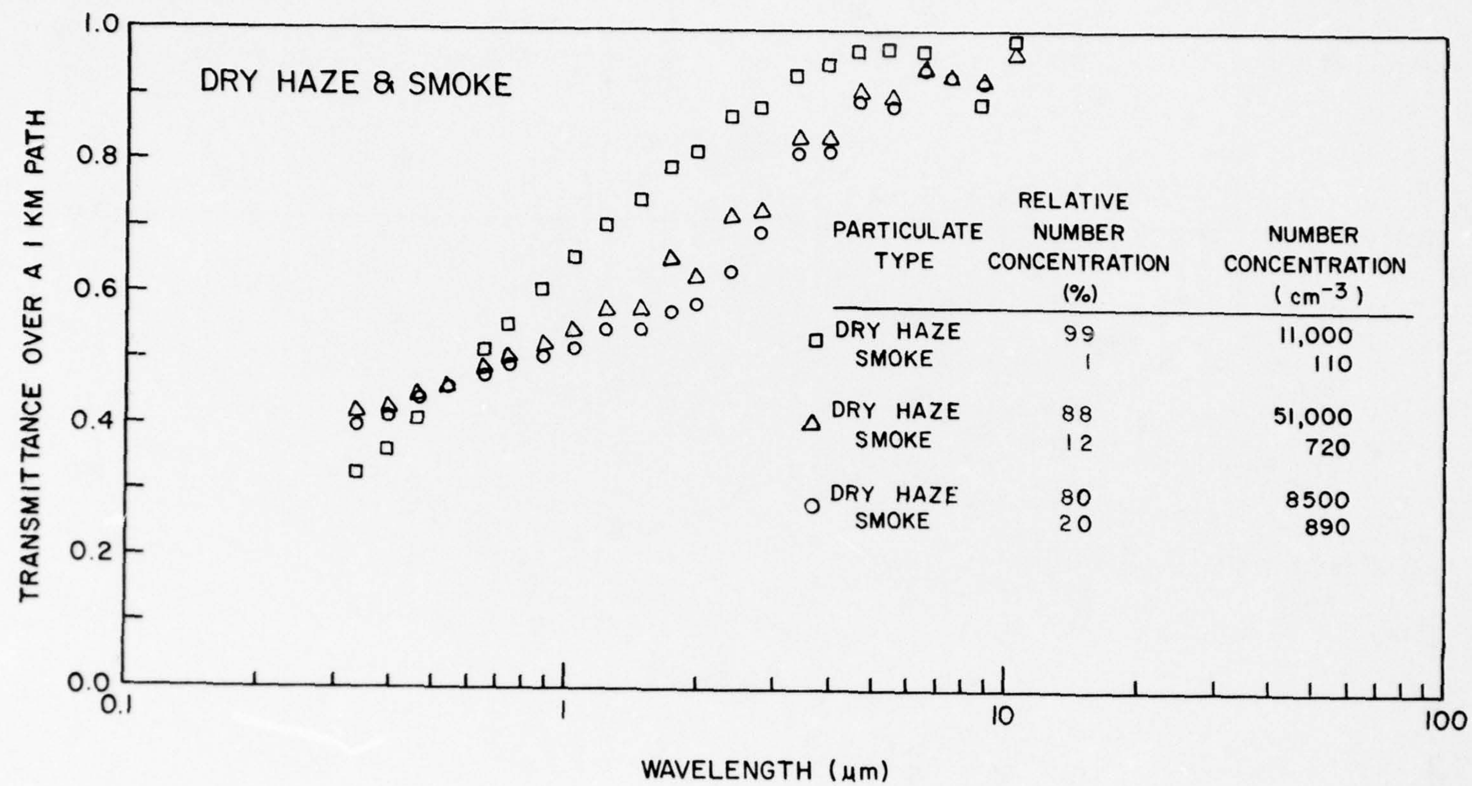


Figure 1. Calculations of transmittance over a 1 km path for various combinations of dry haze and smoke in the spectral range from 0.34 to 10.6μm. Total concentration is such that visibility as defined on page 6 is 5 km.

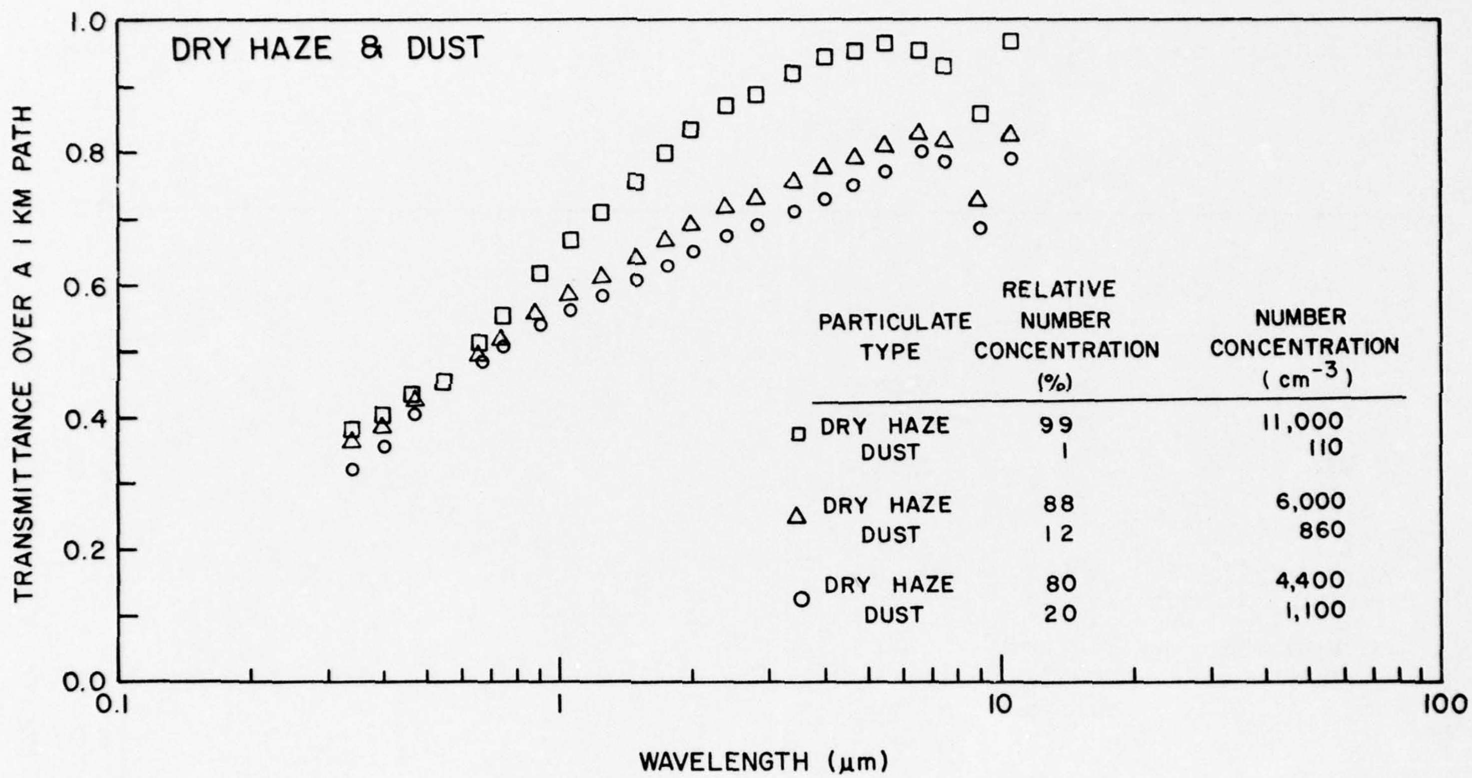


Figure 2. Calculations of transmittance over a 1 km path for various combinations of dry haze and dust in the spectral range from 0.34 to 10.6μm. (visibility = 5 km)

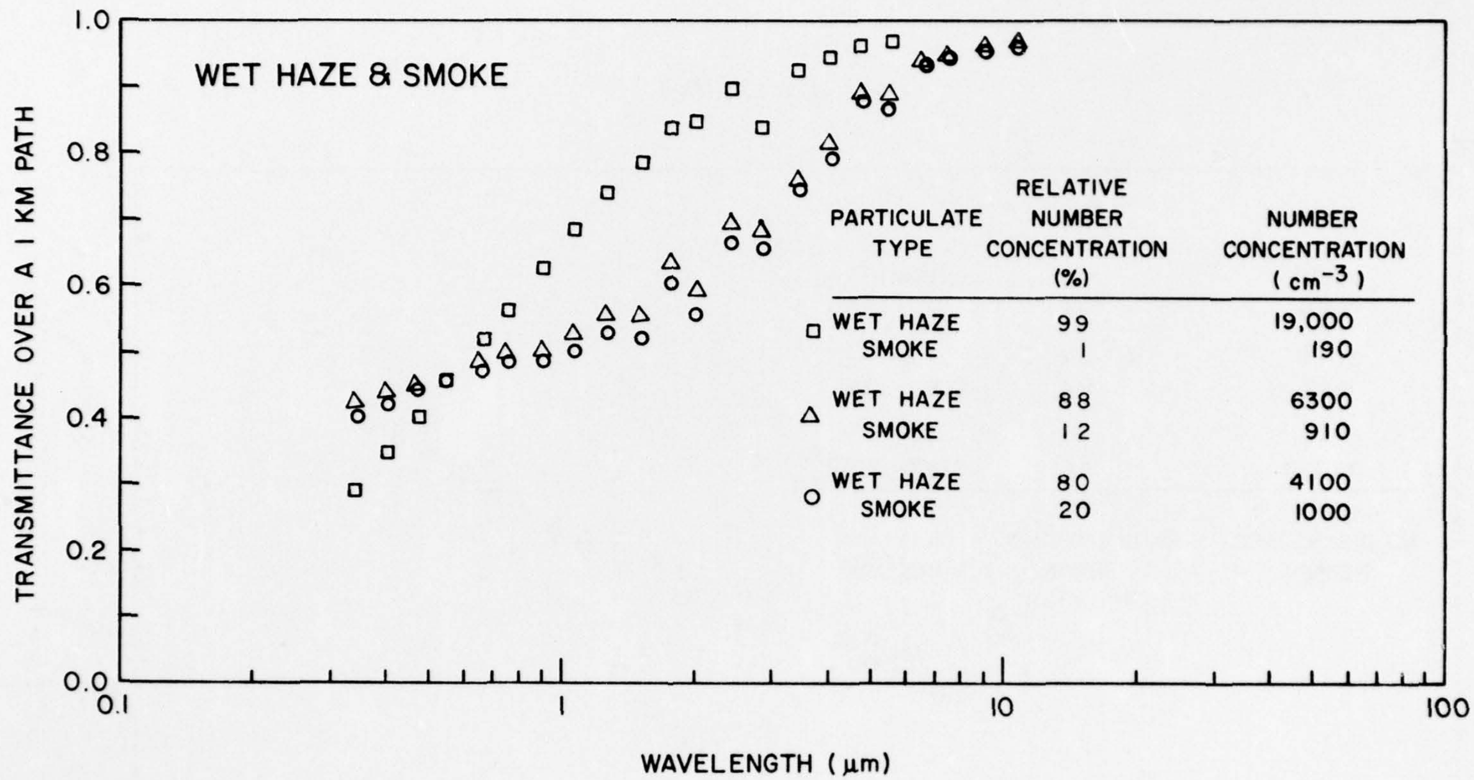


Figure 3. Calculations of transmittance over a 1 km path for various combinations of wet haze and smoke in the spectral range from 0.34 to 10.6μm. (visibility = 5 km)

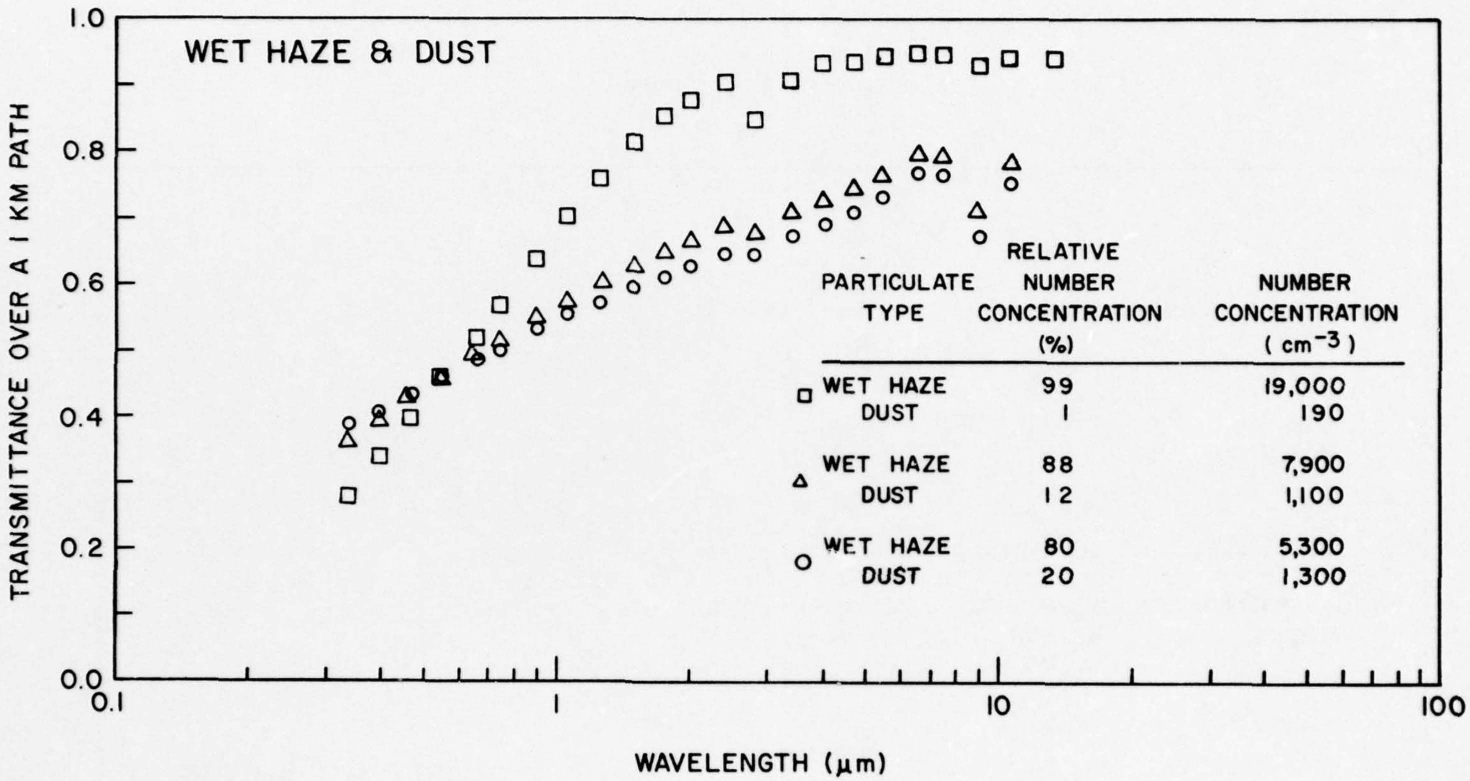


Figure 4. Calculations of transmittance over a 1 km path for various combinations of wet haze and dust in the spectral range from 0.34 to 10.6μm. (visibility = 5 km)

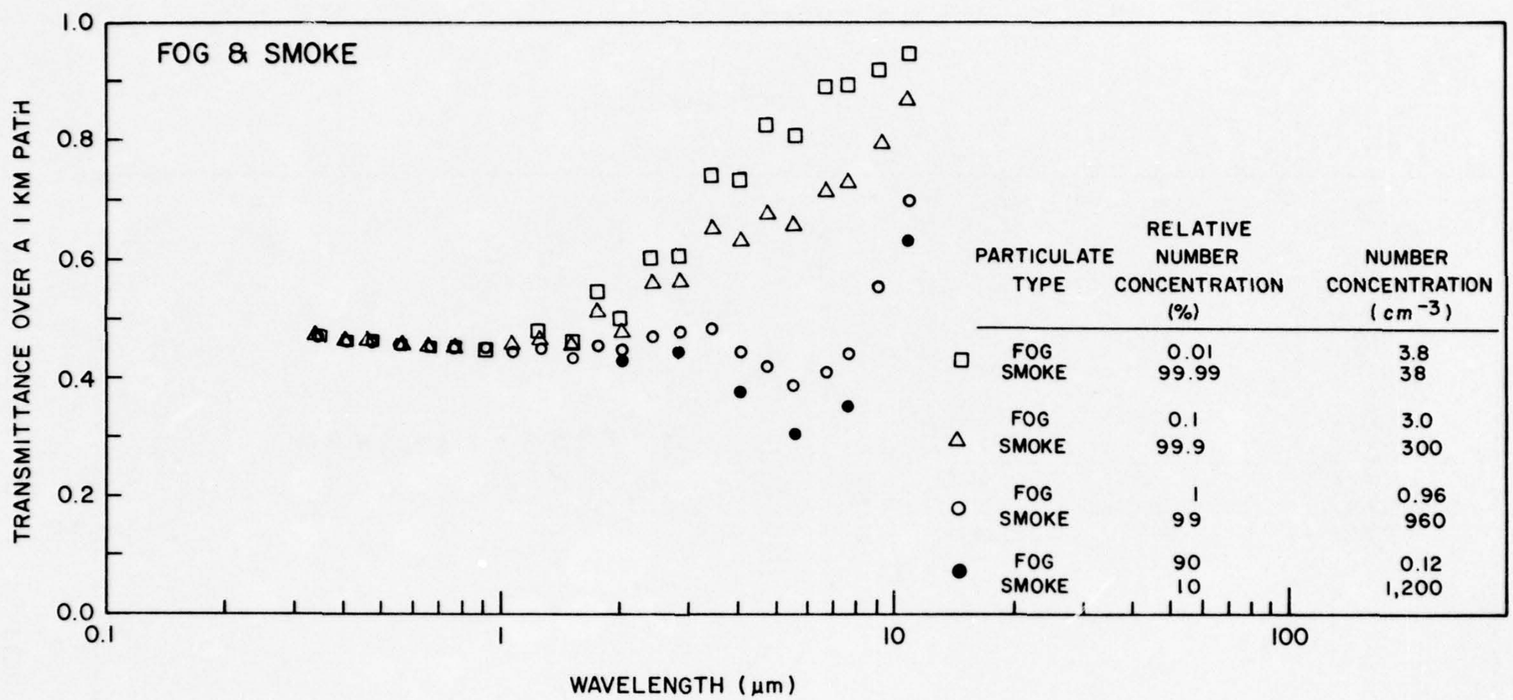


Figure 5. Calculations of transmittance over a 1 km path for various combinations of fog and smoke in the spectral range from 0.34 to 10.6μm. (visibility = 5 km)

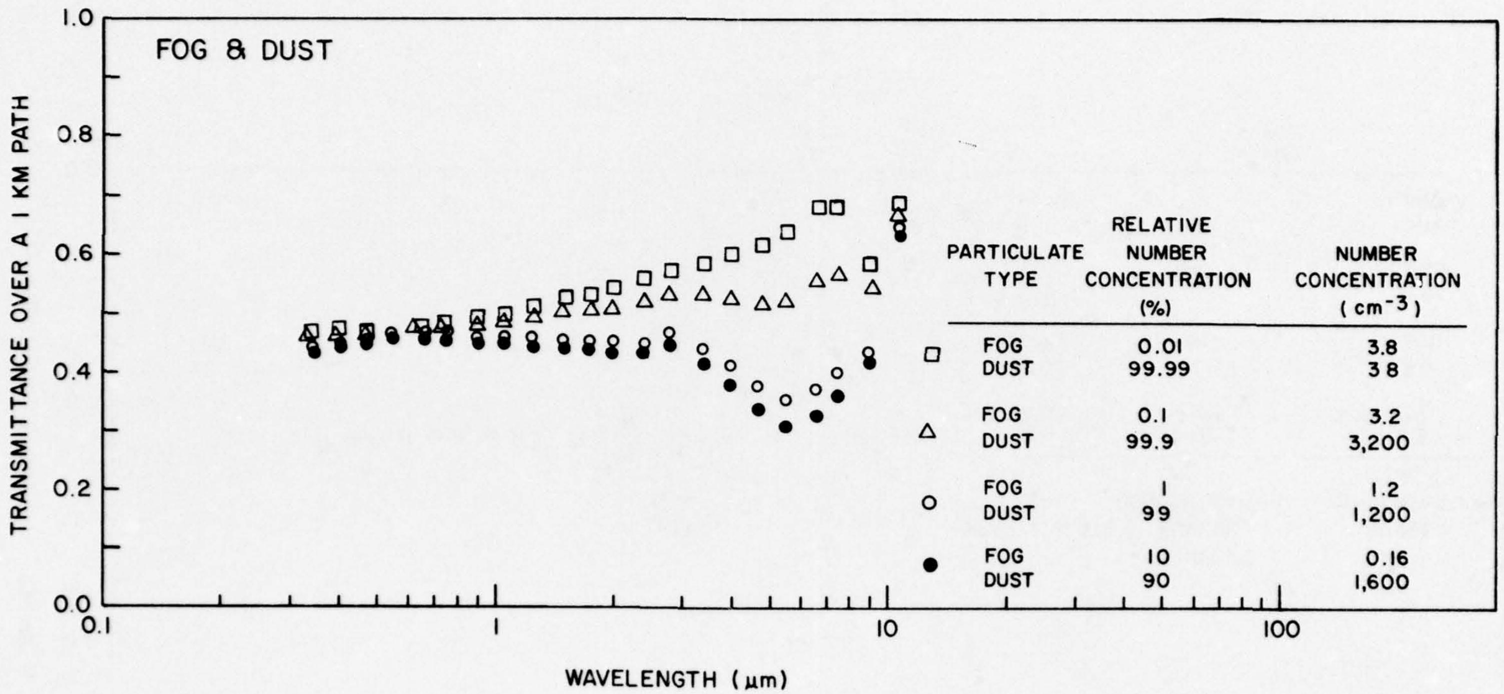


Figure 6. Calculations of transmittance over a 1 km path for various combinations of fog and dust in the spectral range from 0.34 to 10.6μm. (visibility = 5 km)

REFERENCES

1. Kruse, P. W., L. D. McGlauchlin, and R. B. McQuistan, 1962, Elements of Infrared Technology, J. Wiley & Sons, New York, (Ch. 5).

2. Widenhofer, G. and H. Bates, 1967, "Analytical Determination of Laser Pulse Energy for Illuminated Target Detection or Tracking Systems," US Army Missile Command Report RE-TR-67-12.

3. Gomez, R. B., C. Petracca, C. Querfeld, and G. B. Hoidale, 1975, "Atmospheric Effects for Ground Target Signature Modeling. III. Discussion and Application of the ASL Scattering Model," ECOM-5558, Atmospheric Sciences Laboratory, US Army Electronics Command, White Sands Missile Range, NM, 34 pp. (AD A009722)

4. Hoidale, G. B. and J. B. Mason, 1976, "Atmospheric Measurements in Support of the Night Vision Laboratory Field Validation Measurement Series," ECOM-DR-76-2, Atmospheric Sciences Laboratory, US Army Electronics Command, White Sands Missile Range, NM.

5. Ivlev, L. S. and S. I. Popova, 1973, "The Complex Refractive Indices of the Substances in the Atmospheric-aerosol Dispersed Phase," Atmos. Ocean. Phys. (Moscow), 9, 587-591. (English edition)

6. Dalzell, W. H. and A. F. Sarofim, 1969, "Optical Constants of Soot and their Application to Heat-flux Calculations," J. Heat Transfer, 91, 100-104.

7. Twitty, J. T. and J. A. Weinman, 1971, "Radiative Properties of Carbonaceous Aerosols," J. Appl. Meteorol., 10, 725-731.

8. Foster, P. J. and C. R. Howarth, 1968, "Optical Constants of Carbons and Coals in the Infrared," Carbon, 6, 719-729.

9. Hale, G. M. and M. R. Querry, 1973, "Optical Constants of Water in the 200-nm to 200-μm Wavelength Range," Appl. Opt., 12, 555-563.

10. Deirmendjian, D., 1964, "Scattering and Polarization Properties of Water Clouds and Hazes in the Visible and Infrared," Appl. Opt., 3, 187-196.

11. Hänel, G., 1972, "Computation of the Extinction of Visible Radiation by Atmospheric Aerosol Particles as a Function of the Relative Humidity, Based upon Measured Properties," J. Aerosol Sci., 3, 377-386.

12. Middleton, W. E. K., 1958, Vision through the Atmosphere, Univ. Toronto Press, 250 pp.

13. Lentz, W. J. and G. B. Hoidale, 1974, "Estimates of the Extinction of Electromagnetic Energy in the 8 to 12μm Range by Natural Atmospheric Particulate Matter," ECOM-5528, Atmospheric Sciences Laboratory, US Army Electronics Command, White Sands Missile Range, NM. (AD 772960)

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Lindberg, J.D., "An Improvement to a Method for Measuring the Absorption Coefficient of Atmospheric Dust and other Strongly Absorbing Powders," ECOM-5565, July 1975.
2. Avara, Elton, P., "Mesoscale Wind Shears Derived from Thermal Winds," ECOM-5566, July 1975.
3. Gomez, Richard B. and Joseph H. Pierluissi, "Incomplete Gamma Function Approximation for King's Strong-Line Transmittance Model," ECOM-5567, July 1975.
4. Blanco, A.J. and B.F. Engebos, "Ballistic Wind Weighting Functions for Tank Projectiles," ECOM-5568, August 1975.
5. Taylor, Fredrick J., Jack Smith, and Thomas H. Pries, "Crosswind Measurements through Pattern Recognition Techniques," ECOM-5569, July 1975.
6. Walters, D.L., "Crosswind Weighting Functions for Direct-Fire Projectiles," ECOM-5570, August 1975.
7. Duncan, Louis D., "An Improved Algorithm for the Iterated Minimal Information Solution for Remote Sounding of Temperature," ECOM-5571, August 1975.
8. Robbiani, Raymond L., "Tactical Field Demonstration of Mobile Weather Radar Set AN/TPS-41 at Fort Rucker, Alabama," ECOM-5572, August 1975.
9. Miers, B., G. Blackman, D. Langer, and N. Lorimier, "Analysis of SMS/GOES Film Data," ECOM-5573, September 1975.
10. Manquero, Carlos, Louis Duncan, and Rufus Bruce, "An Indication from Satellite Measurements of Atmospheric CO_2 Variability," ECOM-5574, September 1975.
11. Petracca, Carmine and James D. Lindberg, "Installation and Operation of an Atmospheric Particulate Collector," ECOM-5575, September 1975.
12. Avara, Elton P. and George Alexander, "Empirical Investigation of Three Iterative Methods for Inverting the Radiative Transfer Equation," ECOM-5576, October 1975.
13. Alexander, George D., "A Digital Data Acquisition Interface for the SMS Direct Readout Ground Station—Concept and Preliminary Design," ECOM-5577, October 1975.
14. Cantor, Israel, "Enhancement of Point Source Thermal Radiation Under Clouds in a Nonattenuating Medium," ECOM-5578, October 1975.
15. Norton, Colburn and Glenn Hoidale, "The Diurnal Variation of Mixing Height by Month over White Sands Missile Range, NM," ECOM-5579, November 1975.
16. Avara, Elton P., "On the Spectrum Analysis of Binary Data," ECOM-5580, November 1975.
17. Taylor, Fredrick J., Thomas H. Pries, and Chao-Huan Huang, "Optimal Wind Velocity Estimation," ECOM-5581, December 1975.
18. Avara, Elton P., "Some Effects of Autocorrelated and Cross-Correlated Noise on the Analysis of Variance," ECOM-5582, December 1975.
19. Gillespie, Patti S., R.L. Armstrong, and Kenneth O. White, "The Spectral Characteristics and Atmospheric CO_2 Absorption of the Ho^{+3}:YLF Laser at 2.05μm," ECOM-5583, December 1975.
20. Novlan, David J., "An Empirical Method of Forecasting Thunderstorms for the White Sands Missile Range," ECOM-5584, February 1976.
21. Avara, Elton P., "Randomization Effects in Hypothesis Testing with Autocorrelated Noise," ECOM-5585, February 1976.
22. Watkins, Wendell R., "Improvements in Long Path Absorption Cell Measurement," ECOM-5586, March 1976.

23. Thomas, Joe, George D. Alexander, and Marvin Dubbin, "SATTEL — An Army Dedicated Meteorological Telemetry System," ECOM-5587, March 1976.
24. Kennedy, Bruce W. and Delbert Bynum, "Army User Test Program for the RDT&E-XM-75 Meteorological Rocket," ECOM-5588, April 1976.
25. Barnett, Kenneth M., "A Description of the Artillery Meteorological Comparisons at White Sands Missile Range, October 1974 — December 1974 ('PASS' — Prototype Artillery [Meteorological] Subsystem)," ECOM-5589, April 1976.
26. Miller, Walter B., "Preliminary Analysis of Fall-of-Shot From Project 'PASS'," ECOM-5590, April 1976.
27. Avara, Elton P., "Error Analysis of Minimum Information and Smith's Direct Methods for Inverting the Radiative Transfer Equation," ECOM-5591, April 1976.
28. Yee, Young P., James D. Horn, and George Alexander, "Synoptic Thermal Wind Calculations from Radiosonde Observations Over the Southwestern United States," ECOM-5592, May 1976.
29. Duncan, Louis D. and Mary Ann Seagraves, "Applications of Empirical Corrections to NOAA-4 VTPR Observations," ECOM-5593, May 1976.
30. Miers, Bruce T. and Steve Weaver, "Applications of Meterological Satellite Data to Weather Sensitive Army Operations," ECOM-5594, May 1976.
31. Sharenow, Moses, "Redesign and Improvement of Balloon ML-566," ECOM-5595, June 1976.
32. Hansen, Frank V., "The Depth of the Surface Boundary Layer," ECOM-5596, June 1976.
33. Pinnick, R.G. and E.B. Stenmark, "Response Calculations for a Commercial Light-Scattering Aerosol Counter," ECOM-5597, July 1976.
34. Mason, J. and G.B. Hoidale, "Visibility as an Estimator of Infrared Transmittance," ECOM-5598, July 1976.

DISTRIBUTION LIST

Commanding Officer
Picatinny Arsenal
ATTN: SARPA-TS-S, #59
Dover, NJ 07801

Commanding Officer
Harry Diamond Laboratory
ATTN: Library
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Electronics Command
ATTN: DRSEL-RD-D
Fort Monmouth, NJ 07703

Naval Surface Weapons Center
Code DT 21 (Ms. Greeley)
Dahlgren, VA 22448

Air Force Weapons Laboratory
ATTN: Technical Library (SUL)
Kirtland AFB, NM 87117

Director
US Army Engr Waterways Exper Sta
ATTN: Library Branch
Vicksburg, MS 39180

Commander
US Army Electronics Command
ATTN: DRSEL-CT-D
Fort Monmouth, NJ 07703

Meteorologist in Charge
Kwajalein Missile Range
PO Box 67
APO
San Francisco, CA 96555

Environmental Protection Agency
Meteorology Laboratory
Research Triangle Park, NC 27711

Chief, Technical Services Div
DCS/Aerospace Sciences
ATTN: AWS/DNTI
Scott AFB, IL 62225

Air Force Cambridge Rsch Labs
ATTN: LCH (A. S. Carten, Jr.)
Hanscom AFB
Bedford, MA 01731

Department of the Air Force
16WS/DO
Fort Monroe, VA 23651

Director
US Army Ballistic Research Lab
ATTN: DRXBR-AM
Aberdeen Proving Ground, MD 21005

Geophysics Division
Code 3250
Pacific Missile Test Center
Point Mugu, CA 93042

National Center for Atmos Res
NCAR Library
PO Box 3000
Boulder, CO 80303

William Peterson
Research Association
Utah State University, UNC 48
Logan, UT 84322

Commander
US Army Dugway Proving Ground
ATTN: MT-S
Dugway, UT 84022

Head, Rsch and Development Div (ESA-131)
Meteorological Department
Naval Weapons Engineering Support Act
Washington, DC 20374

Commander
US Army Electronics Command
ATTN: DRCDE-R
5001 Eisenhower Avenue
Alexandria, VA 22304

Marine Corps Dev & Educ Cmd
Development Center
ATTN: Cmd, Control, & Comm Div (C^3)
Quantico, VA 22134

Commander
US Army Electronics Command
ATTN: DRSEL-WL-D1
Fort Monmouth, NJ 07703

Commander
US Army Missile Command
ATTN: DRSMI-RFGA, B. W. Fowler
Redstone Arsenal, AL 35809

Dir of Dev & Engr
Defense Systems Div
ATTN: SAREA-DE-DDR
H. Tannenbaum
Edgewood Arsenal, APG, MD 21010

Mr. William A. Main
USDA Forest Service
1407 S. Harrison Road
East Lansing, MI 48823

Naval Surface Weapons Center
Technical Library and Information
Services Division
White Oak, Silver Spring, MD 20910

Dr. A. D. Belmont
Research Division
PO Box 1249
Control Data Corp
Minneapolis, MN 55440

Dir, Elec Tech and Devices Lab
US Army Electronics Command
ATTN: DRSEL-TL-D, Bldg 2700
Fort Monmouth, NJ 07703

Director
Development Center MCDEC
ATTN: Firepower Division
Quantico, VA 22134

Commander
US Army Proving Ground
ATTN: Technical Library, Bldg 2100
Yuma, AZ 85364

US Army Liaison Office
MIT-Lincoln Lab, Library A-082
PO Box 73
Lexington, MA 02173

Library-R-51-Tech Reports
Environmental Research Labs
NOAA
Boulder, CO 80302

Head, Atmospheric Research Section
National Science Foundation
1800 G. Street, NW
Washington, DC 20550

Commander
US Army Missile Command
ATTN: DRSMI-RR
Redstone Arsenal, AL 35809

Commandant
US Army Field Artillery School
ATTN: Met Division
Fort Sill, OK 73503

Meteorology Laboratory
AFCRL/LY
Hanscom AFB
Bedford, MA 01731

Commander
US Army Engineer Topographic Lab
(STINFO CENTER)
Fort Belvoir, VA 22060

Commander
US Army Missile Command
ATTN: DRSMI-RRA, Bldg 7770
Redstone Arsenal, AL 35809

Air Force Avionics Lab
ATTN: AFAL/TSR
Wright-Patterson AFB, Ohio 45433

Commander
US Army Electronics Command
ATTN: DRSEL-VL-D
Fort Monmouth, NJ 07703

Commander
USAICS
ATTN: ATSI-CTD-MS
Fort Huachuca, AZ 85613

E&R Center
Bureau of Reclamation
ATTN: Bldg 67, Code 1210
Denver, CO 80225

HQDA (DAEN-RDM/Dr. De Percin)
Forrestal Bldg
Washington, DC 20314

Commander
Air Force Weapons Laboratory
ATTN: AFWL/WE
Kirtland AFB, NM 87117

Commander
US Army Satellite Comm Agc
ATTN: DRCPM-SC-3
Fort Monmouth, NJ 07703

Commander
US Army Electronics Command
ATTN: DRSEL-MS-TI
Fort Monmouth, NJ 07703

Commander
US Army Electronics Command
ATTN: DRSEL-GG-TD
Fort Monmouth, NJ 07703

Dr. Robert Durrenberger
Dir, The Lab of Climatology
Arizona State University
Tempe, AZ 85281

Commander
Headquarters, Fort Huachuca
ATTN: Tech Ref Div
Fort Huachuca, AZ 85613

Field Artillery Consultants
1112 Becontree Drive
ATTN: COL Buntyn
Lawton, OK 73501

Commander
US Army Nuclear Agency
ATTN: ATCA-NAW
Building 12
Fort Bliss, TX 79916

Director
Atmospheric Physics & Chem Lab
Code 31, NOAA
Department of Commerce
Boulder, CO 80302

Dr. John L. Walsh
Code 5503
Navy Research Lab
Washington, DC 20375

Commander
US Army Air Defense School
ATTN: C&S Dept, MSLSCI Div
Fort Bliss, TX 79916

Director National Security Agency
ATTN: TDL (C513)
Fort George G. Meade, MD 20755

USAF EPAC/CBT (Stop 825)
ATTN: Mr. Burgmann
Scott AFB, IL 62225

Armament Dev & Test Center
ADTC (DLOSL)
Eglin AFB, Florida 32542

Commander
US Army Ballistic Rsch Labs
ATTN: DRXBR-IB
Aberdeen Proving Ground, MD 21005

Director
Naval Research Laboratory
Code 2627
Washington, DC 20375

Commander
Naval Elect Sys Cmd HQ
Code 51014
Washington, DC 20360

The Library of Congress
ATTN: Exchange & Gift Div
Washington, DC 20540
2

CO, US Army Tropic Test Center
ATTN: STETC-MO-A (Tech Lib)
APO New York 09827

Commander
Naval Electronics Lab Center
ATTN: Library
San Diego, CA 92152

Office, Asst Sec Army (R&D)
ATTN: Dep for Science & Tech
Hq, Department of the Army
Washington, DC 20310

Director
US Army Ballistic Research Lab
ATTN: DRXBR-AM, Dr. F. E. Niles
Aberdeen Proving Ground, MD 21005

Commander
Frankford Arsenal
ATTN: Library, K2400, Bldg 51-2
Philadelphia, PA 19137

Director
US Army Ballistic Research Lab
ATTN: DRXBR-XA-LB
Bldg 305
Aberdeen Proving Ground, MD 21005

Dir, US Naval Research Lab
Code 5530
Washington, DC 20375

Commander
Office of Naval Research
Code 460-M
Arlington, VA 22217

Commander
Naval Weather Service Command
Washington Navy Yard
Bldg 200, Code 304
Washington, DC 20374

Technical Processes Br
D823
Room 806, Libraries Div NOAA
8060 13th St
Silver Spring, MD 20910

The Environmental Rsch Institute of MI
ATTN: IRIA Library
PO Box 618
Ann Arbor, MI 48107

Redstone Scientific Info Center
ATTN: Chief, Documents
US Army Missile Command
Redstone Arsenal, AL 35809

Commander
Edgewood Arsenal
ATTN: SAREA-TS-L
Aberdeen Proving Ground, MD 21010

Sylvania Elec Sys Western Div
ATTN: Technical Reports Library
PO Box 205
Mountain View, CA 94040

Commander
US Army Security Agency
ATTN: IARD-OS
Arlington Hall Station
Arlington, VA 22212
2

President
US Army Field Artillery Board
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-TA-R
Fort Sill, OK 73503

CO, USA Foreign Sci & Tech Center
ATTN: DRXST-ISI
220 7th Street, NE
Charlottesville, VA 22901

Commander, Naval Ship Sys Cmd
Technical Library, Rm 3 S-08
National Center No. 3
Washington, DC 20360

Commandant
US Army Signal School
ATTN: ATSN-CD-MS
Fort Gordon, GA 30905

Rome Air Development Center
ATTN: Documents Library
TILD (Bette Smith)
Griffiss Air Force Base, NY 13441

HQ, ESD/DRI/S-22
Hanscom AFB
MA 01731

Commander
Frankford Arsenal
ATTN: J. Helfrich PDSP 65-1
Philadelphia, PA 19137

Director
Defense Nuclear Agency
ATTN: Tech Library
Washington, DC 20305

Department of the Air Force
5WW/DOX
Langley AFB, VA 23665

Commander
US Army Missile Command
ATTN: DRSMI-RER (Mr. Haraway)
Redstone Arsenal, AL 35809

CPT Hugh Albers, Exec Sec
Interdept Committee on Atmos Sci
Fed Council for Sci & Tech
National Sci Foundation
Washington, DC 20550

US Army Research Office
ATTN: DRXRO-IP
PO Box 12211
Research Triangle Park, NC 27709

Commander
US Army Training & Doctrine Cmd
ATTN: ATCD-SC
Fort Monroe, VA 23651

Mil Assistant for Environmental Sciences
OAD (E & LS), 3D129
The Pentagon
Washington, DC 20301

Commander
Eustis Directorate
US Army Air Mobility R&D Lab
ATTN: Technical Library
Fort Eustis, VA 23604

National Weather Service
National Meteorological Center
World Weather Bldg - 5200 Auth Rd
ATTN: Mr. Quiroz
Washington, DC 20233

Commander
US Army Materiel Command
ATTN: DRCRD-SS (Mr. Andrew)
Alexandria, VA 22304

Commander
Frankford Arsenal
ATTN: SARFA-FCD-O, Bldg 201-2
Bridge & Tarcony Sts
Philadelphia, PA 19137

Inge Dirmhirn, Professor
Utah State University, UMC 48
Logan, UT 84322

Chief, Aerospace Environ Div
Code ES41
NASA
Marshall Space Flight Center, AL 35802

Dr. Frank D. Eaton
PO Box 3038
University Station
Laramie, Wyoming 82071

Commander
US Army Arctic Test Center
ATTN: STEAC-OP-PL
APO Seattle 98733

Commander
US Army Electronics Command
ATTN: DRSEL-GS-H (Stevenson)
Fort Monmouth, NJ 07703

Commander
USACACDA
ATTN: ATCA-CCC-W
Fort Leavenworth, KS 66027

Commander
US Army Test & Eval Cmd
ATTN: DRSTE-FA
Aberdeen Proving Ground, MD 21005

Air Force Cambridge Rsch Labs
ATTN: LKI
L. G. Hanscom Field
Bedford, MA 01730

Director, Systems R&D Service
Federal Aviation Administration
ATTN: ARD-54
2100 Second Street, SW
Washington, DC 20590

USAFETAC/CB (Stop 825)
Scott AFB
IL 62225

Director
USAE Waterways Experiment Station
ATTN: Library
PO Box 631
Vicksburg, MS 39180

Defense Documentation Center
ATTN: DDC-TCA
Cameron Station (BLDG 5)
Alexandria, Virginia 22314
12

Commander
US Army Electronics Command
ATTN: DRSEL-CT-S
Fort Monmouth, NJ 07703

Commander
Holloman Air Force Base
6585 TG/WE
Holloman AFB, NM 88330

Commandant
USAFAS
ATTN: ATSF-CD-MT (Mr. Farmer)
Fort Sill, OK 73503
2

Commandant
USAFAS
ATTN: ATSF-CD-C (Mr. Shelton)
Fort Sill, OK 73503
2

Commander
US Army Electronics Command
ATTN: DRSEL-CT-S (Dr. Swingle)
Fort Monmouth, NJ 07703
3

☆ U.S. GOVERNMENT PRINTING OFFICE: 1976—677-344/55